Mr Somerville

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# BBC

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# MONOGRAPH

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## Drop-out in video tape recording

by

W. K. E. GEDDES, M.A.(Cantab.), Grad.I.E.E.
(Research Department, BBC Engineering Division)

PART I

THE SUBJECTIVE IMPAIRMENT PRODUCED BY DROP-OUTS

PART II

A SIMPLE DROP-OUT COMPENSATOR FOR VIDEO TAPE RECORDERS

BRITISH BROADCASTING CORPORATION

PRICE FIVE SHILLINGS

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# FOREWORD

THIS is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six are produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph describes work that has been done by the Engineering Division of the BBC and includes, where appropriate, a survey of earlier work on the same subject. From time to time the series may include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

This series should be of interest and value to engineers engaged in the fields of broadcasting and of telecommunications generally.

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## PREVIOUS ISSUES IN THIS SERIES

# DROP-OUT IN VIDEO TAPE RECORDING

## SUMMARY

Part I of this monograph describes test procedures for assessing the subjective impairment produced by various forms of 'drop-out' interference in video tape recordings. As a result of the assessments it is concluded that the subjective acceptability of a tape's drop-out performance may be predicted by means of a simple meter, and design parameters for such a meter are derived.

Part II gives a brief description of a simple device that considerably reduces the subjective impairment. Tests similar to those described in Part I indicate the degree of improvement to be expected from such a device.

# PART I

# THE SUBJECTIVE IMPAIRMENT PRODUCED BY DROP-OUTS

## 1. Introduction to Part I

During the playback of video tape recordings, sporadic, momentary loss of the reproduced signal takes place as a result of microscopic blemishes on the tape; these blemishes may interrupt the recording process, the reproducing process, or both. A typical drop-out lasts some five or ten microseconds and causes, in the case of Ampex machines of the VR1000 series, a peak-white fleck in the reproduced picture.* The frequency at which drop-outs occur depends largely upon the properties of the particular tape; an exceptionally good tape may exhibit only two or three drop-outs per minute, but it is not uncommon to encounter tapes having mean drop-out rates of five or ten per minute, together with occasional 'bursts' during which several drop-outs occur within a second or two. The severity of impairment caused by drop-outs is lessened if a greater 'tip-penetration' is employed;† this technique is resorted to by some operators who are prepared to accept the higher rate of head wear which results.

The drop-out activity of each new tape is assessed as part of its acceptance tests. The current practice is to record a video signal of constant level throughout the tape, and then to monitor the replay visually on a picture monitor. This method has the disadvantage that the assessment arrived at depends largely on the judgement of the individual operator and has the further disadvantage of requiring the undivided attention of the operator for the full replay time.

Two types of drop-out counter allowing drop-out activity to be assessed automatically have recently been devised. In the first of these[1] each drop-out causes a deflection proportional to its duration to be recorded on a moving chart, and the total cumulative duration of the drop-outs is also recorded. The second type[2] records, on electromechanical counters, the total number of drop-outs and the number of occasions on which more than a certain number of drop-outs occur within a given interval. However, in the absence of any quantitative data on the subjective perception of drop-outs, both the specification of such counters and the interpretation of their results must remain somewhat arbitrary. The tests described in this report were carried out in order to furnish this data.

A by-product of the investigation has been to demonstrate the feasibility of an objective instrument whose response to drop-outs correlates well with the associated subjective impairment of picture quality.

* The survey described in this monograph was chiefly concerned with the impairments produced by drop-outs of this type. R.C.A. machines and the Ampex VR2000 produce a black-level video signal when drop-out occurs and the associated subjective effects have been assessed in subsidiary tests which are described in Section 5.

† 'Tip-penetration' is a term defining the extent to which the protruding pole-pieces of the rotating heads press into the tape as they sweep across it.

## 2. Description of Experiments

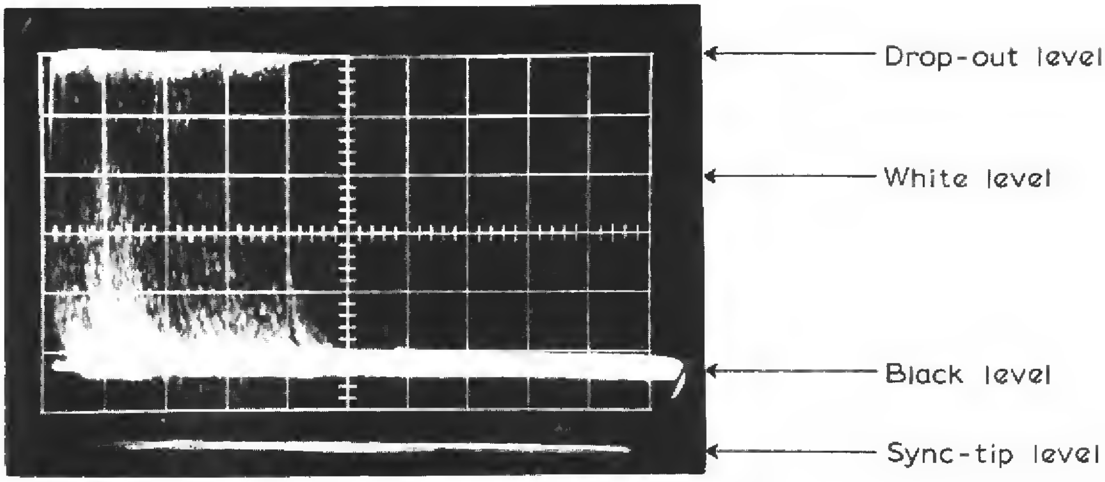
### 2.1 *Apparatus*

The objective parameters of drop-outs cannot, because of their random nature, be concisely defined and it is therefore impracticable to establish a significant correlation between these parameters and the associated subjective impairments. For this reason simulated drop-outs of controllable duration and frequency were used in the experiments.

In order to establish the range of duration exhibited by real drop-outs, long-exposure photographs of a reproduced video waveform were taken, in which all the drop-outs occurring within a five-minute period were superimposed. A recording of black-level was made on a length of tape that had been rejected as unfit for operational use owing to excessive drop-out activity. The recording was then played back and the reproduced video signal displayed on an oscilloscope whose timebase was triggered whenever the video signal increased beyond a level corresponding to mid-grey.

The oscilloscope had a trace speed of 5 $\mu$s/cm and a trace length of 10 cm; it thus displayed the video waveform only during the 50 $\mu$s immediately following the start of a drop-out. Fig. 1 shows the photograph obtained by taking a five-minute exposure of the display. It will be seen that the frequency of occurrence tended to decrease for drop-outs of duration above about 15 $\mu$s and that virtually no drop-outs of duration greater than 25 $\mu$s occurred.

Fig. 1 applies to a head having a tip-penetration of about 0·0025 in. The frequency of drop-outs is known to




*Horizontal scale: 5μs per graticule line*

*Fig. 1 — Long-exposure photograph of video waveform, showing distribution and range of drop-out duration*

increase considerably as the head wears and the tip-penetration decreases, and a second photograph was taken, using a penetration of 0·0015 in., in order to find out whether decreased penetration also caused an increase in the maximum duration of drop-outs. It was found that the number of longer drop-outs increased slightly, but the number of drop-outs of duration greater than 25μs was very small. The equipment constructed for simulation of drop-outs was therefore arranged to provide pulses having durations of 3μs, 6μs, 12μs, and 24μs.

These pulses were used to interrupt the frequency-modulated signal entering the replay circuits of an Ampex 1000C tape-recorder, and Fig. 2 shows schematically the arrangement employed.

The recorder was used in the so-called 'EE' (Electronic-Electronic) mode, in which the frequency-modulated signal that is normally fed to the recording head is connected instead to a point near the input of the replay chain. A video signal is thus subjected to all the purely electronic processing associated with recording and reproduction without actually undergoing either process, and momentary interruption of the signal at the point where it passes from the recording to the replay circuits exactly simulates a drop-out in an actual tape replay. With the switch (see Fig. 2) in the 'continuous' position, the pulse generator interrupted the modulated carrier repeatedly at the pulse repetition frequency, thus producing a steady train of drop-outs. By setting the switch to 'burst', drop-outs could be made to occur only during the period of a further pulse (whose duration was adjustable to values of $\frac{1}{4}$, $\frac{1}{2}$, and 1 second), which was initiated manually. The white limiter in the replay circuits of the recorder was set to operate at a voltage level of 10 per cent above the nominal maximum video voltage.

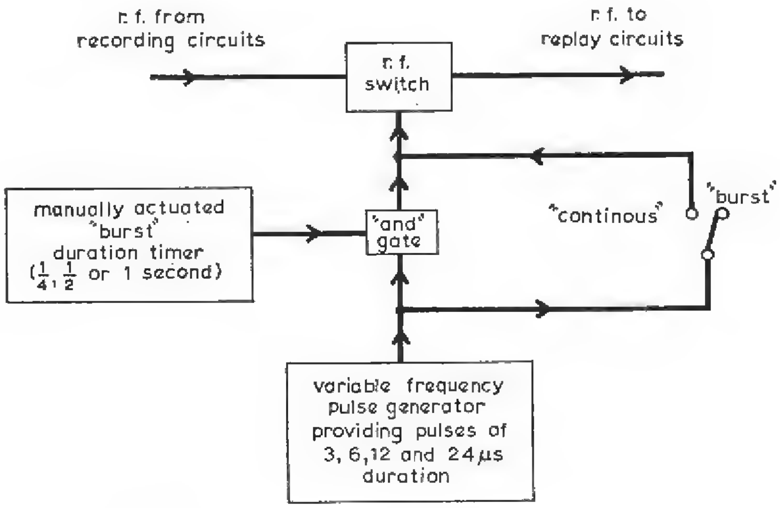



*Fig. 2 — Schematic diagram of arrangements for simulating drop-outs*

The resulting picture was displayed on a monitor synchronized from separate synchronizing pulses that were not affected by drop-outs. This accords with the BBC's practice of feeding the output of a video tape recorder through a flywheel sync-pulse regenerator, which replaces any synchronizing pulses in the reproduced signal that have been impaired by drop-outs. The effect of omitting such a regenerator is discussed in Section 6. The picture was viewed by the observers under the following conditions.

| | |
|---|---|
| Television standard: | 625 lines |
| Picture source: | 35 mm flying-spot telecine |
| Size of display: | 21 in. (53 cm) diagonal |
| Viewing distance: | 6 × picture height |
| Peak luminance: | 25 ft-L (268 asb) |
| Ambient illumination: | 0·5 ft-L (5·4 asb) |

(Luminance of a white card alongside the display)

### 2.2 *Subjective-test Procedure*

During preliminary tests it was found that when an observer deliberately kept watch for drop-outs in a tape-recorded programme he noticed them very much more than when he watched the programme as entertainment. The difference was, in fact, so marked that it was felt that any results obtained by observers concentrating on the drop-outs rather than on the pictures would be quite irrelevant to the appraisal of drop-outs as a practical problem.

Avoidance of this pitfall in subjective testing obviously demands the use of pictures having some measure of interest to the observer and the tests were therefore carried out using moving pictures, with sound. For convenience, the pictures were obtained from film, although it was realized that the blemishes inevitably present on film might interfere with the assessment of impairment due to drop-outs. In the event, however, it was found that the observers had no difficulty in distinguishing drop-outs from film blemishes (which were in any case slight) and little error is thought to have resulted from this cause. In all, seven reels of documentary films were used, each lasting fifteen to twenty minutes, and the observers did not consider that they had become unduly bored by the films even at the end of the tests. The use of varied programme material had the disadvantage of yielding a very low return of results for a given expenditure of testing time, because each form of drop-out interference had to be assessed several times, at different points in the film, in order to average variations due to the particular type of picture upon which the drop-outs were superimposed.

It is here convenient to define three terms that will be used in describing the experiments. These are:

Sequence: A series of drop-outs whose moments of occurrence are defined.

Test: A particular presentation of a sequence; each subjective grade quoted is the mean grade for all tests using a particular sequence.

Set of tests: All of the tests involving several sequences of related character.

The observers were television engineers accustomed to the critical appraisal of television pictures.

At the end of each test they wrote down, using the six-point grading scale discussed below, the extent to which they felt their enjoyment was, at that moment, impaired by the presence of drop-outs; announcements defining the beginning and end of each test were superimposed on the sound signal. Each set of tests included some six or eight different sequences of drop-outs and each sequence was used for two tests during each of two viewing sessions. Each set of tests was seen by ten observers, five during each session. Thus, each result quoted is the mean of twenty individual results; the order in which the various sequences were presented was changed whenever the same reel of film was used for both sessions.

### 2.3 *Subjective Grading Scale*

Pilot experiments were carried out using the BBC six-point impairment scale (which is the same as that shown below, but with the words in parentheses omitted); however, observers stated that they found the scale confusing. They found, for example, that drop-outs separated by long intervals might be 'definitely perceptible' at their moments of occurrence yet, because of their infrequency, constitute too trivial an impairment to merit the comparatively adverse assessment implied by a grading of '3'.

The scale was therefore supplemented by displaying a further set of verbal descriptions in parentheses alongside the established set, as follows:

| | |
|---|---|
| 1. Imperceptible | (no impairment) |
| 2. Just perceptible | (negligible impairment) |
| 3. Definitely perceptible but not disturbing | (slight impairment) |
| 4. Somewhat objectionable | (marked impairment) |
| 5. Definitely objectionable | (severe impairment) |
| 6. Unusable | (complete impairment) |

These terms appeared to be acceptable to the observers, although it should be pointed out that, since it is not anticipated that tapes exhibiting severe drop-out impairment will ever be used, the level of impairment imposed in the tests was so restricted that grades 4 and 5 were used very seldom, and grade 6 not at all.

### 2.4 *Scope of the Tests*

It is evident that no tests can provide results that are directly applicable to the practical problem of assessing real drop-outs because real drop-outs, being of a random nature, never occur in the exact sequences used in the tests. What is to be expected from the tests is that they should provide data enabling random sequences of drop-outs to be assessed, from objective measurements, in a way that correlates closely with the subjective impairment they produce. Ideally, the data should make it possible to calculate from the pattern of occurrence of any sequence of drop-outs the impairment grading that an observer would record if asked to assess that sequence.

The three sets of tests carried out in order to achieve this objective were quantitative investigations of factors whose effects are qualitatively obvious.

In set 'A', each test consisted of impairing the pictures for about a minute by simulated drop-outs having defined values of duration and repetition rate. Various pairs of values were used in these tests and from the results it was possible to establish the manner in which impairment increases with the values of these two parameters.

In set 'B', picture impairment was assessed at the moment of cessation of simulated drop-outs that had been sustained, at a given repetition rate, for various periods. By establishing the manner in which the impairment increased as the drop-outs were sustained for progressively longer periods, these tests indicated the extent to which previous drop-outs continue to influence current assessments.

In set 'C', the impairment produced by a given number of simulated drop-outs was assessed for various values of the interval between successive drop-outs. Qualitative prediction of the results was not possible in this case because, although increasing the interval between drop-outs reduced their occurrence rate, it increased the time during which the picture was impaired. The object of this set of tests was primarily to determine which of these two opposing effects predominated.

## 3. Results

### 3.1 *General*

The results of set 'A', which are given in Table 1, show that picture impairment increases with both the duration and the repetition rate of the drop-outs, as was expected. The dotted lines join results corresponding to the same total duration of drop-outs occurring in one second; it will be seen that, for a given total duration, impairment increases somewhat as the drop-outs become shorter but more frequent.

TABLE 1

*Mean Subjective Impairment Gradings of Regularly Recurring Drop-outs*

| | *Repetition Rate of Drop-outs (pulses per second)* 0·125 | 0·25 | 0·5 | 1·0 | 2·0 |
|---|---|---|---|---|---|
| Duration of 3 | | | 1·55 | 2·15 | 2·70 |
| drop-outs 6 | | 1·45 | 1·75 | 2·20 | |
| (μs) 12 | 1·45 | 1·50 | 2·15 | | |

In the various tests of set 'B', 12μs drop-outs at 0·5 p.p.s., 6μs drop-outs at 1 p.p.s., and 3μs drop-outs at 2 p.p.s. were each sustained for periods of 8, 16, 32, and 64 seconds. The means of the gradings recorded immediately after the cessation of the drop-outs are shown in Table 2.

TABLE 2

*Results of Tests in which Simulated Drop-outs were Sustained for Various Periods*

| *Duration for which Drop-outs Sustained (seconds)* | *Mean Subjective Grade* |
|---|---|
| 8 | 1·6 |
| 16 | 1·83 |
| 32 | 2·23 |
| 64 | 2·27 |

These results indicate that an assessment of impairment is not influenced by that part of the train of drop-outs which occurs more than about half a minute before the assessment is made.

This conclusion was confirmed by the results of a subsidiary set of tests in which the pictures were impaired by short bursts of simulated drop-outs. The duration of each burst was constant but the number of bursts in each sequence and the duration of the intervals separating the bursts were both varied. It was found that when the bursts were separated by 8- or 16-second intervals, appreciable build-up of impairment took place as the number of bursts in the test was increased; however, when the intervals were 32 seconds long, repeated bursts produced little more impairment than did a single burst.

The results of set 'C' are plotted in Fig. 3 in which the crosses show the impairment grade assigned to a sequence of eight 6μs drop-outs as a function of the interval between successive drop-outs. The eight drop-outs may be seen to produce maximum impairment when their separa-

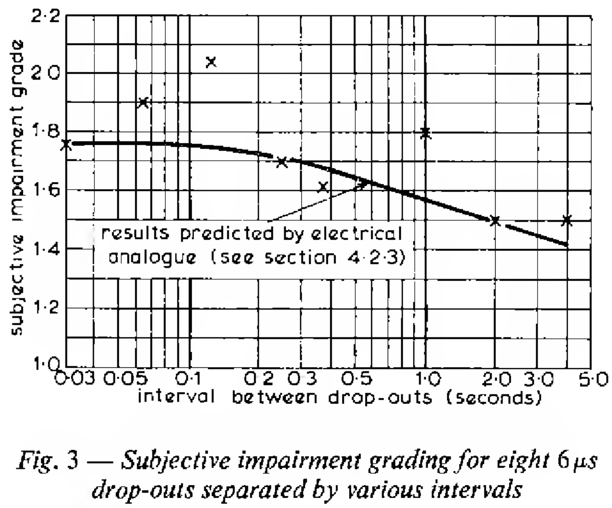



*Fig. 3 — Subjective impairment grading for eight 6μs drop-outs separated by various intervals*

tion is 0·125 seconds. The decline in impairment that takes place as the interval between successive drop-outs increases beyond this value is consistent with the hypothesis that each drop-out produces a subjective 'impact', which declines with the observer's remembrance of its occurrence, and that the sense of impairment obtaining at any moment is a summation of the residual impacts of all previous drop-outs. As a given number of drop-outs are spread over a longer period, therefore, the residual impacts of the earlier ones become progressively less at the moment of assessment, and the impairment grading decreases correspondingly.

3.2 *Consistency of the Results*

In general, each sequence of drop-outs was assessed twice by each of two groups of five observers. Different picture content was used for each assessment, and the order of disagreement between the two mean gradings awarded by a given group shows the extent to which the grading is affected by the picture content. From a random selection of thirty such pairs of assessments the r.m.s. value of this disagreement has been found to be 0·56 of a grade. When this comparison was similarly applied to two assessments of a given drop-out sequence made by two different groups of observers, exactly the same r.m.s. value of disagreement was obtained, indicating that disagreement was primarily due to variations in picture content rather than to differences between observers. The standard deviation of the four assessments of each drop-out sequence has been found, for twenty-two sequences, to be 0·34 of a grade.

Determining the degree of disagreement between observers is complicated by the use of a grading scale confined to integers. If, for example, the real value of impairment were 2·0, all observers would ideally record a grade of 2, whereas if the real impairment value were 2·5 the best that could be hoped for is that observers would be evenly divided between grades 2 and 3. If, however, for the same test, individual observers record results spanning three or more grades, this proves that there is a divergence of opinion of a magnitude related to the proportion of tests in which this happens. In the present experiments it has been found that the group of five observers confined their gradings to two adjacent grades for 73 per cent of the tests; gradings spanned three grades in 26 per cent of the tests, and in 1 per cent of the tests they spanned four grades.

## 4. Objective Assessment by Means of an Analogue Circuit

4.1 *General*

The results of the tests show that an observer's impression of impairment is reinforced by successive drop-outs but decays during the intervals between them. This conclusion suggests that a workably valid analogue of the subjective processes involved might well be provided by an electrical circuit whose response to a succession of stimuli similarly consists of reinforcement and decay. The response of such a circuit to a signal derived from the individual drop-outs of a random sequence would provide a moment-by-moment indication of impairment and the circuit could therefore form the basis of a 'drop-out meter', calibrated in subjective impairment grades.

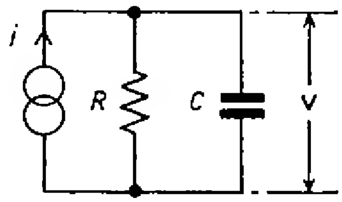



*Fig. 4 — Proposed circuit for simulating subjective perception of drop-outs*

Fig. 4 shows a simple circuit that might be expected to exhibit suitable behaviour. It is assumed that the current $i$ would flow only when a drop-out was occurring. Since the time constant of the circuit is assumed to be several orders of magnitude longer than the duration of a drop-out, the current generator would place on the capacitor C, during each drop-out, a charge $q$ related to the duration of the drop-out. The voltage $V$ existing across the capacitor and its shunting resistor $R$ could then be taken as a moment-by-moment measure of drop-out activity and could, for example, be recorded on a moving chart by means of a recording voltmeter. The waveform of $V$ would consist of a series of positive-going steps, each representing the subjective impact of the associated drop-out, separated by periods of slow exponential decay towards zero; this implies that the decline in the subjective impression left by previous drop-outs is exponential and is characterized by a 'time constant of forgiveness' equal to the product $CR$.

The means available for fitting the performance of such an analogue circuit to experimental data are as follows:

(i) Choice of the voltage-step per drop-out, $q/C$, for various values of drop-out duration. It cannot be assumed that the correct weighting of drop-outs of various lengths results from the use of a constant charging current $i$. It is reasonable to assume, however, that impairment, and hence $q/C$, increases with duration so that the charging current $i$ is uni-directional.

(ii) Calibration of the output voltage in terms of the subjective impairment grade; there is no *a priori* reason why these two quantities should be linearly related.

(iii) Choice of the time constant $CR$.

4.2 *Derivation of Design Parameters*

In order to investigate the validity of the analogue circuit, a set of design parameters has been deduced from the results of the subjective tests. The gradings that would have been recorded in response to the drop-out sequences used in the tests, by a hypothetical meter embodying these parameters, have been calculated and compared with those actually recorded by the observers. The design parameters have been chosen, on a trial-and-error basis, with the object

of providing acceptable agreement with the total volume of experimental data.

4.2.1 *Choice of the Voltage Step per Drop-out*

Fig. 5 is a re-presentation of the data for set 'A' already set out in Table 1. The ordinates are the subjective grades recorded for the various test sequences, and the abscissae are the peak output voltages that each sequence would produce in a meter employing the chosen parameters. The values of the quantity $q/C$, for various values of drop-out duration, are chosen so as to yield a single curve that relates voltage to grade. For $3\mu s$, $6\mu s$, and $12\mu s$ drop-outs, the values of $q/C$ are respectively in the ratios $0{\cdot}75 : 1 : 1{\cdot}5$. The quantity of charge supplied to $C$ during each drop-out should not, therefore, be directly proportional to drop-out duration but should increase relatively rapidly with duration up to $3\mu s$ and increase linearly, but less rapidly, for greater values of duration. This condition may be met by arranging for the current $i$ to decline from an initial peak during the first $3\mu s$ of each drop-out, then maintain a constant value for the remainder of the drop-out; this assumption is consistent with the very limited data collected for a drop-out duration of $24\mu s$.

4.2.2 *Calibration of Output Voltage in Terms of Subjective Grade*

The curve of Fig. 5, which shows the relationship between voltage and grade, may be seen to exhibit a change of about 2 : 1 in slope over the range of impairments explored. The scale of voltage has been arbitrarily chosen to give a slope of one grade per volt at low values of impairment. The precise value chosen for the time constant of the circuit is of little significance as it is much longer than the maximum interval between drop-outs, and the value of 14 seconds assumed is a compromise between the values of 16 seconds and 12 seconds respectively indicated by the results of sets 'B' and 'C'.

4.2.3 *Choice of Time Constant*

When the analogue circuit is stimulated by a regular succession of identical drop-outs, the peak values of voltage approach equilibrium exponentially, with a time constant equal to that of the circuit, as shown in Fig. 6. The results of set 'B' established the impairment produced by such regular trains of drop-outs as a function of the period for which they were sustained, and it should therefore be possible, if the circuit is valid, to fit an exponential curve to these results, provided that the impairment gradings are first transformed to values of voltage by means of the curve of Fig. 5.

Fig. 7 shows the results of set 'B' plotted in this way, together with an exponential curve corresponding to a time constant of 14 seconds; this may be seen to fit the data fairly well although, as mentioned above, a slightly better fit can be obtained in this case by assuming a time constant of 16 seconds.

As may be seen from Fig. 6, when the analogue circuit attains a state of dynamic equilibrium under a steady incidence of drop-outs, the exponential decline of voltage between drop-outs is just equal to the step of voltage that each drop-out produces. If the time constant, the peak voltage under equilibrium conditions, and the recurrence frequency are all defined, then the value of this voltage step is also defined; the response of the analogue circuit to the isolated bursts of drop-outs used in set 'C' can thus be predicted from the results of the 'steady-state' tests of set 'A'. A curve has been added to the results of set 'C', plotted in Fig. 3, which shows the impairment grading predicted from the output voltage of the analogue circuit; the value of voltage step assumed is that defined by the results of set 'A', and the time constant is assumed to be 14 seconds. In general, the predicted grade is rather lower than the measured grade, indicating that so far as this set of tests is concerned a higher value of voltage step, and hence a shorter time constant, should have been assumed in deriving the curve from the data for regular sequences; in this case a value of about 12 seconds would yield the best agreement. However, the manner in which the impairment decreases as the drop-outs become more widely separated is quite satisfactorily predicted. The slight decrease in impairment that takes place as the burst of drop-outs becomes very short is not, of course, reproducible by the analogue circuit.

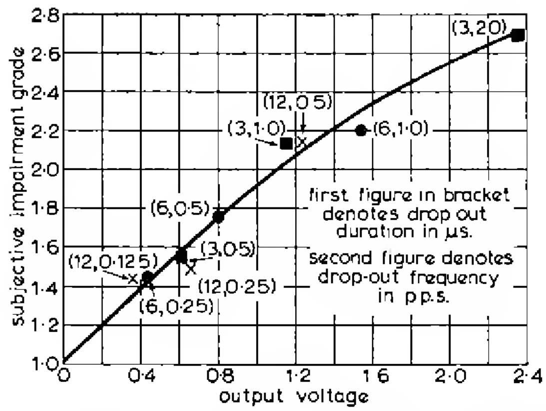



*Fig. 5 — Subjective impairment gradings of regularly recurring drop-outs, plotted against output voltage of electrical analogue*

4.3 *Agreement with Experimental Data*

In order to provide a quantitative indication of the validity of the circuit discussed, the subjectively determined impairment gradings assigned to twenty-six different drop-out sequences used in the tests have been compared with the gradings which would be predicted by the analogue circuit, and the r.m.s. deviation between the two has been evaluated. The twenty-six chosen sequences comprised the nine shown in Fig. 5, the eight shown in Fig. 3, and nine of the twelve used in the derivation of Fig. 7; the remaining three, being derived from regular trains each lasting 64 seconds, were already covered by Fig. 5. The r.m.s. deviation was found to be just under $0{\cdot}2$ of a sub-

*Fig. 6 — Exponential rise of peak voltage when voltage steps are imposed on parallel combination of* C *and* R

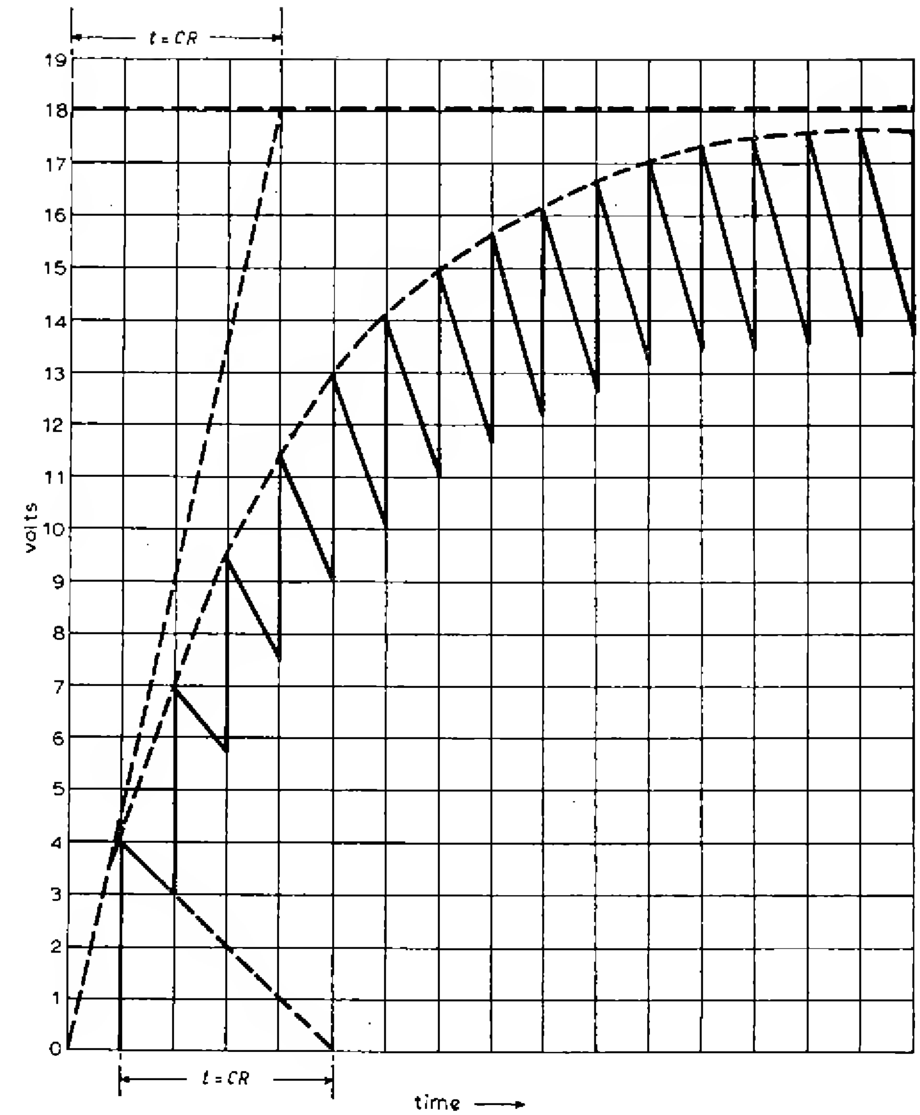
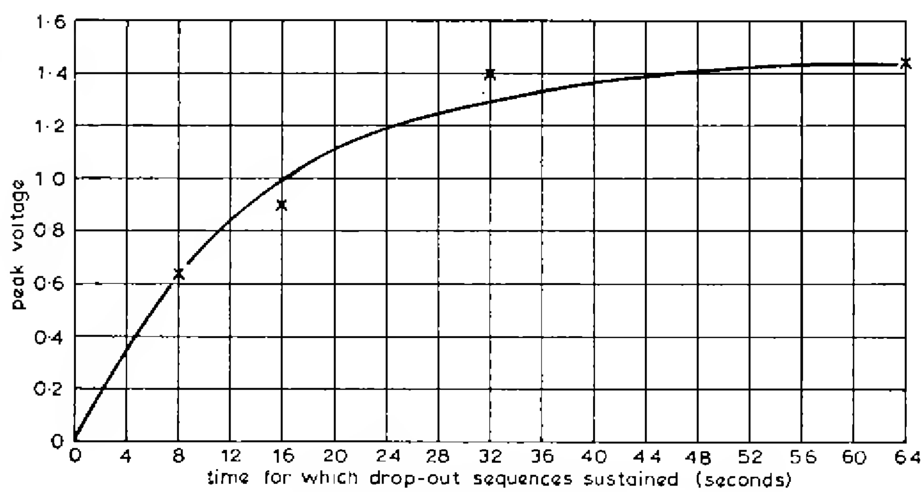



*Fig. 7 — Exponential rise in peak voltage (time constant = 14 seconds) compared with voltages implied by corresponding subjective grading*



jective grade. The individual gradings differed by more than $0 \cdot 3$ of a grade only twice, when $3 \mu s$ drop-outs at 2 p.p.s. were sustained for 8 and 16 seconds. In both these cases the predicted value was about $0 \cdot 5$ of a grade worse than that recorded subjectively.

## 5. Extension of the Tests to Black Drop-outs

In extending the tests to include the assessment of black drop-outs it was found necessary to make several changes in the experimental arrangements. No video recorder producing black drop-outs was available so the drop-outs were simulated by straightforward video-frequency techniques, without the use of any video tape recording equipment.

It was also found to be necessary to use, as the displayed video signal, 'live' television rather than a signal derived from a film scanner; this was because it became evident that when black drop-outs were being assessed the masking effect of film blemishes, which are predominantly black, could no longer be ignored as it had been in the assessment of white drop-outs. When live television was used as the source of video signals it was found convenient to use the 405-line standard instead of the 625-line standard. A subsidiary experiment was therefore carried out using white drop-outs in order to establish whether this change of line standard itself caused a significant difference in the impairment produced by a drop-out of given spatial length. A film was scanned at one standard for the first half of each testing session and at the other standard for the second half; each half contained the same sequence of drop-outs but with drop-out durations suitably adjusted to maintain the same spatial length in corresponding sequences at the two standards. Comparison of subjective gradings for the two standards revealed no significant difference.

Sets of tests, using 'live' outside broadcasts of sporting events were then carried out, in which black drop-outs were used for some tests and white drop-outs for others. It was found that black drop-outs produced considerably less impairment than did white, for a given sequence; for example, a sustained sequence of $9\frac{1}{2} \mu s$ drop-outs (equivalent to $6 \mu s$ on the 625-line standard) at a rate of four drop-outs per second was judged to have an impairment grading of $3 \cdot 65$ when the drop-outs were white, but only $2 \cdot 45$ when they were black. The difference is more fundamentally expressed, however, in terms of the relative rates at which black and white drop-outs must respectively occur in order to produce the same degree of impairment. It was found that, for a given degree of impairment, black drop-outs must occur about three times as often as white ones.

It might, in fact, have been anticipated that black drop-outs would be found to produce less impairment than white ones. Because the response/stimulus relationship of the eye is roughly logarithmic, the visibility of a disturbance of luminance, such as drop-out, depends not on the absolute change of luminance involved, but on the ratio of the change in luminance to the original luminance. Over most of the area of most television pictures the luminance is considerably less than half that of white areas, and an excursion to black therefore corresponds to a smaller value of the above-mentioned ratio than does an excursion to white. In near-white areas, of course, black drop-outs are more visible than white ones, but this factor may be expected to be more than outweighed by the very high ratios of luminance change to original luminance that white drop-outs produce in dark areas.

If it ever became necessary to assess tapes that were to be used only with machines producing black drop-outs, the assessment criterion would have to be modified to take account of the lower visibility of black drop-outs. The type of meter discussed in this report, for example, could be suitably modified by reducing the charging current $i$ to one-third of its previous value. So long as machines producing white drop-outs are extant, however, it is anticipated that the more stringent criterion will be retained, in order to maintain the interchangeability of tape stock.

## 6. Interference with Synchronization

It is the BBC's operational practice to feed the output of all video tape recorders through flywheel sync-pulse regenerators which replace isolated synchronizing pulses lost as a result of drop-outs. Not all broadcasting authorities protect receiver synchronization in this way, however, and isolated synchronizing pulses may therefore be missing from the radiated signal. 'Hard-lock' domestic receivers are thus susceptible to additional impairment from drop-outs as a result of interference with synchronization.

In order to assess the magnitude of this effect, a subsidiary experiment was carried out using a 405-line domestic receiver with hard-lock synchronization. This was fed with an r.f. signal modulated by a video signal marred by simulated white drop-outs. The drop-outs could be inhibited from affecting the signal during blanking intervals in order to provide a control condition giving protection of synchronization. Subjective tests were then carried out in which identical drop-out sequences were used with and without protection of synchronization.

It was found that the effect of removing protection from the synchronizing pulses is approximately equivalent to increasing the drop-out repetition rate in the ratio of $1 \cdot 5 : 1$.

## 7. Conclusions on Part I

The tests described have established the subjective impairments produced by sustained regular sequences of identical simulated drop-outs, for several values of drop-out duration and repetition frequency. They show that, for white drop-outs having typical values of duration, rates as high as 15 per minute produce assessments more or less equally divided between 'no impairment' and 'negligible impairment', with very few assessments of 'slight impair-

ment'; black drop-outs can occur three times as frequently as white for a given degree of impairment. It is possible that these results may be found to be slightly optimistic, in that the documentary films and outside broadcasts used as subject-matter during the tests included more movement than occurs in typical studio programmes, and may have constituted a correspondingly greater distraction from the drop-outs.

Extension of the tests to include less regular sequences of drop-out has indicated the feasibility of an objective meter whose readings would correlate satisfactorily with subjective impairment over the range of drop-out phenomena usually encountered, and has enabled the parameters of such a meter to be evaluated with a precision adequate for the design of a prototype. It is intended to construct a prototype meter and to compare its readings with subjective assessments when real, as opposed to simulated, drop-outs are present.

# PART II

# A SIMPLE DROP-OUT COMPENSATOR FOR VIDEO TAPE RECORDERS

## 8. Introduction to Part II

During playback of video tape recordings, momentary loss of the reproduced signal takes place, sporadically, as a result of microscopic blemishes on the tape; these blemishes may interrupt the recording process, the replay process, or both. 'Drop-outs' are typically of some five or ten microseconds' duration and occur at mean intervals of a few seconds. The effect of a drop-out on the output of the recorder depends on the particular circuit arrangements used for recovering the video information from the recorded frequency-modulated signal. In machines of the Ampex 1000 series the drop-out appears as a peak-white fleck, whereas in R.C.A. and Ampex 2000 series machines it produces a 'blacker-than-black' video signal, which causes less subjective impairment.

The ill effects of drop-outs can be mitigated by the use of some form of 'compensator' which, during the occurrence of a drop-out, replaces the distorted video signal by a substitute signal. This substitute cannot, of course, restore the video information missing from the reproduced signal, but can render its loss less obvious. In the simplest form of compensator the missing video signal is replaced by a constant, manually adjustable, level during all drop-outs; a compensator of this type is used in the Ampex 2000. Brief use of an experimental circuit utilizing this principle has revealed that, while some improvement is undoubtedly achieved with a carefully chosen level of substitute signal, drop-outs are still very noticeable in areas where the substituted level differs markedly from the correct level.

A more sophisticated form of compensator incorporates a video delay of one line-period, which enables the video information from the previous line to be substituted during drop-outs; in one version the bandwidth of the video delay is about 1 Mc/s. The performance is extremely good, but the unit cost is £1,700.

This report contains a brief description of a type of compensator* which is relatively cheap and which, it is thought, may adequately meet the needs of operational service. An experimental model has been built, and assessed by means of simulated drop-outs; a second specimen, of similar design but fully developed for actuation by real drop-outs, is currently under construction by the BBC's Operations and Maintenance Department for operational trials.

* Independently proposed by both G. D. Monteath and the writer.

## 9. Description of Compensator

Drop-outs are obvious in a displayed picture largely because of the difference between their luminance and the mean luminance of the surrounding picture area. A useful reduction in their visibility might thus be expected to result from any process tending to match their luminance to that of their surroundings. In the compensator to be described, the commencement of a drop-out causes the video output voltage to be maintained at the level that obtained immediately beforehand, until the instant at which an undistorted video signal can be restored. It should be noted that this type of compensator, unlike that employing a one-line delay, cannot restore the shape of a synchronizing pulse that has been marred by a drop-out.

The compensator and its connexions to the recorder are shown schematically in Fig. 8. The compensator is inserted into the video signal path between the output of the discriminator and the input of the processor. Normally the change-over switch connects the incoming video signal directly to the output of the compensator and the diode switch conducts, so that the voltage on the storage capacitor follows the video signal. Whenever the amplitude of the frequency-modulated signal from the output of the head switcher falls by more than, say, 6 dB, the change in the output of the first detector causes the diode switch to become non-conducting, thereby maintaining the video-signal voltage then existing on the storage capacitor. Should the level of the r.f. signal subsequently fall to, say, 30 dB below normal, the change in the output of the second detector causes the change-over switch to operate, and the voltage stored on the capacitor appears at the output of the compensator in place of the video signal, until the r.f. level recovers at the end of the drop-out. Both detector/switch combinations incorporate a degree of 'backlash' in order to avoid premature restoration of normal conditions.

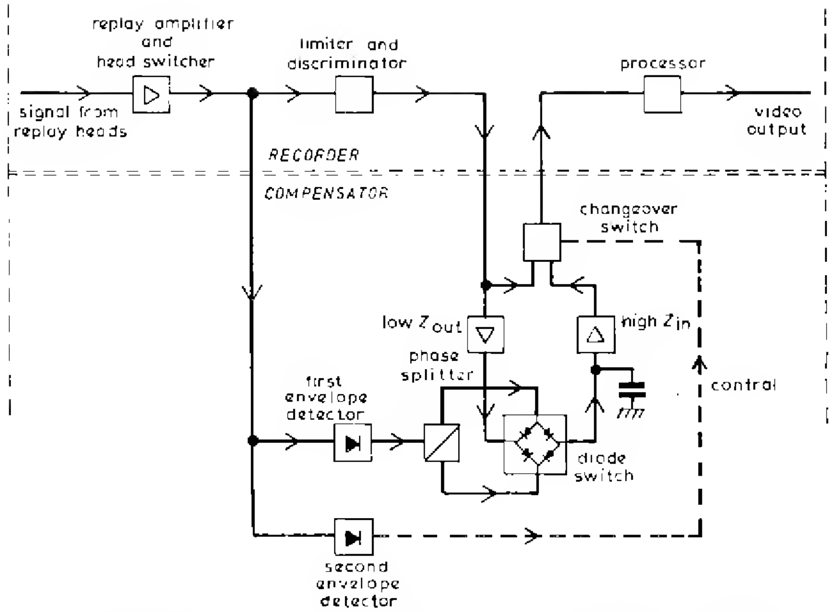



*Fig. 8 — Block schematic diagram showing compensator connected to video tape recorder*

The use of two detectors, each with its own threshold level,* permits independent control of the sampling of the video signal and of its replacement by the substitute signal. The fall of r.f. level at the beginning of a drop-out is not instantaneous, but typically extends over a period of the order of a microsecond. The threshold level of the first detector is set to a value only a few decibels below normal, and the video waveform is therefore sampled before it begins to exhibit distortion due to the drop-out. When drop-outs correspond to an ultimate fall of, say, 15 to 25 dB in r.f. amplitude, the limiters in the recorder effectively restore the video signal after an initial burst of distortion, and the uncompensated video signal is then subjectively preferable to the substitute signal. The threshold of the second detector is therefore set to operate the change-over switch only when the r.f. level falls below that at which the limiters fail; by choosing the threshold in this way the substitute signal is used only when it is subjectively preferable to the signal it replaces.

## 10. Subjective Assessment of the Compensator

Subjective tests, utilizing simulated drop-outs of known duration and repetition rate, were carried out in order to assess the benefit to be expected from use of the compensator.

### 10.1 *Experimental Arrangements*

Prior to display on a picture monitor, a video signal was passed either through the compensator or through a drop-out simulator; both circuits were actuated by the same 'drop-out' pulse generator, which supplied pulses of known duration and repetition rate. In the compensator, these pulses were substituted for the outputs of its detectors and, therefore, caused the compensator to operate as though a drop-out had occurred. In the simulator, the video signal was replaced, during each pulse, by a constant voltage which could be set to black-level or to a level 10 per cent above white. Signals containing either black or white drop-outs could thus be compared with the output of the compensator, which is not affected by the type of drop-out.

* Suggested by E. R. Rout.

### 10.2 *Experimental Procedure and Results*

A group of five observers, who were television engineers, watched 405-line pictures of sporting events displayed on a high-grade 21-in. monitor. The pictures, which were viewed from a distance of six times the picture height, had a peak-white luminance of 25 ft-L (268 a.s.b.) and the ambient illumination was such as to reflect a luminance of 0·5 ft-L (5·4 a.s.b.) from a white card alongside the display. In each test, of which there were eighteen in a session, simulated drop-outs having a chosen combination of duration and repetition rate were imposed for a period of one minute; tests involving black, white, and compensated drop-outs were mixed in random sequence. The beginning and end of each test was identified by announcements superimposed on the sound channel of the programme and at the end of each test the observers recorded the extent to which their enjoyment of the programme had been impaired by drop-outs, using the BBC six-point grading scale with additional verbal descriptions, which was given in Clause 2.3 of Part I. The entire session was then repeated using different observers. Only nine different test conditions were used during each session; each was presented in two tests occurring several minutes apart in order to reduce the effect of picture content.

The test conditions were chosen in order to allow the subjective effects of black, white, and compensated drop-outs to be compared in two different ways. It was required to know, first, how the type of drop-out affected the impairment produced by a given combination of duration and repetition rate and, secondly, how it affected the repetition rate necessary to produce a given impairment, assuming a constant value of drop-out duration.

For the first comparison, drop-outs having a duration of about 10 $\mu$s and a repetition rate of four per second were used. The mean gradings for the three types of drop-out were:

| | |
|---|---|
| White drop-outs: | 3·65 |
| Black drop-outs: | 2·45 |
| Compensated drop-outs: | 1·65 |

Thus when the uncompensated drop-outs were white, compensation reduced the impairment by 2·0 grades, and when they were black, by 0·8 of a grade. In order to allow the second comparison to be made, white, black, and compensated drop-outs were assessed for various combinations of duration and frequency, all chosen to produce impairment gradings between 1·5 and 2·5. It was found that, for a given duration of drop-out, very similar impairment gradings were obtained when the respective repetition rates of white, black, and compensated drop-outs were in the ratios 1 : 3 : 8.

Thus, when the uncompensated drop-outs are white, the compensator produces the same improvement in subjective grading as reducing the mean frequency of occurrence to one-eighth of its actual value; when the uncompensated drop-outs are black, using the compensator produces the same improvement as reducing the frequency to three-eighths of its actual value.

## 11. Conclusions on Part II

At the present time many new tapes are rejected because of impairment by drop-outs and the results obtained with the experimental compensator suggest that its use would allow many of these tapes to be accepted and would render completely innocuous the drop-out activity of all tapes at present accepted.

The method of compensation described is, of course, inherently inferior to that which uses a one-line delay. However, it is probable that any tape whose drop-out activity is too great for effective compensation by the simple compensator would in any case be unacceptable to Operations and Maintenance Department, because high drop-out content is often found to be associated with imperfect adhesion between the oxide surface and the tape backing. This may cause one or more heads to become fouled to such an extent as to render a recording quite unusable.

The simple compensator described promises to offer a useful reduction in the subjective impairment produced by drop-outs. Final assessment of the device will be possible when it has been tested with real drop-outs rather than simulated ones.

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